Environmental Perturbations, Behavioral Change, and Population Response in a Long-term Northern Elephant Seal Study

Daniel P. Costa
University of California, Santa Cruz
100 Shaffer Rd.
Santa Cruz, CA 95060
phone: (831) 459-2786 fax: (831) 459-3383 email: costa@biology.ucsc.edu

Award Number: N00014-10-1-0356
www.topp.org

LONG-TERM GOALS

A major challenge in marine mammal conservation and management is to understand how behavioral responses affect populations. To address this challenge, the National Research Council established the Committee on Characterizing Biologically Significant Marine Mammal Behavior. This committee developed a framework for analyzing the population consequences of acoustic disturbance, or PCAD (NRC 2005). The PCAD framework defines a series of transfer functions which describe how behavioral responses to sound affect life functions, how life functions are linked to vital population rates, and how changes in vital rates cause population change (Fig. 1). The U.S. Navy included the PCAD framework in the U.S. Navy Living Marine Resource Sound Research Requirements, specifically within the “Response to Naval Sounds” requirement #5: *Determine biologically significant behavioral responses from Navy sound sources on individuals representing marine mammal species of concern with respect to ... determining long-term effects of behavioral responses and how individual vital rates may affect the population*. This requirement was given the highest priority under the Navy's requirements.

Implementing the concepts of transfer functions which link behavior to population change, however, requires substantial long-term data on individual animals and population size, and there are few marine mammal populations where quantifying the functions is plausible. Funding from this grant has allowed us to extend and improve a four-decade study of northern elephant seal populations in California, aiming specifically to quantify key linkages within the PCAD model. Since 1968, several thousand individual seals have been tagged and tracked for their lifetimes, and several hundred of those have been weighed or outfitted with telemetry devices in order to document pelagic foraging behavior and body condition. The study has spanned the Pacific Decadal Oscillation and several El Niño events and documented how such environmental fluctuations affect individuals and populations. Recent advances in telemetry and our understanding of foraging behavior and body condition allow us to extend this study into the future with improved methods, and with our current funding we have maintained and advanced a classic long-term study of a vertebrate population.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **2010**	2. REPORT TYPE	3. DATES COVERED **00-00-2010 to 00-00-2010**
4. TITLE AND SUBTITLE **Environmental Perturbations, Behavioral Change, and Population Response in a Long-term Northern Elephant Seal Study**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of California, Santa Cruz,100 Shaffer Rd,Santa Cruz,CA,95060**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**8**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

OBJECTIVES

Specifically we have collected data to answer two general questions: 1) How closely coupled are short term changes in foraging behavior to adult fecundity and survival? and 2) Does this link vary with environmental perturbations such as the El Niño Southern Oscillation (ENSO) that are known to impact prey availability? Such data are essential for the population modeling effort currently underway by the PCAD Working Group organized by the Office of Naval Research.

These two questions translate into three hypotheses we are testing:

1) Adult survival fluctuates with ocean climate, with low survival in the year following ENSO events, and higher survival after non-ENSO years.
2) Oceanic climate cycles will impact foraging of pregnant females and weaning weight and survival of pups. Specifically, warming trends (ENSO and “sardine” regimes) will be associated with lowered weaning weights. Survival during the first year at sea will be positively correlated with weaning weight.
3) Population growth potential is limited by these ENSO and Decadal (PDO) impacts on foraging and thus animal condition.

APPROACH

These hypotheses will be tested with data gathered through five research activities, all conducted through an ENSO cycle at the Año Nuevo, California, elephant seal colony: 1) continue annual censuses of the breeding population; 2) measure adult female body condition; 3) weigh weaned pups to link female condition to reproductive output; 4) continue and expand tag re-sighting to refine survival estimates; 5) continue satellite tracking of adult females to map foraging. Lastly, we have expanded and coordinated resighting efforts at two additional elephant seal colonies in central California in order to examine migration between colonies and assess population trends at larger spatial scales.

We will use data collected from these activities, as well as the legacy data of the past 40 years, to parameterize a Bayesian hierarchical population model, then use elasticity analyses to evaluate the links from ocean conditions to adult survival, nursing resources, weaner size, juvenile survival, and population growth. The results will allow us to explore potential population responses to climatic and other perturbations by building demographic models.

El Niño conditions were present across the equatorial Pacific Ocean in mid-2009 which created moderate-to-strong increases in sea surface temperatures during the pupping/breeding winter season of 2009/2010. The National Weather Service Climate Prediction Center anticipate the opposite, La Niña conditions will persist through this coming winterThis is an unusual opportunity to examine how the foraging behavior of a marine mammal responds to a significant decrease in food resources expected with the ENSO as well as potential changes in the species behavior and demographics in response to La Niña conditions following an El Niño . In addition, the long-term seal database spans two prior strong ENSOs, in 1998-99 and 1982-83 (Fielder 2002). Moreover, our results on seals can be placed in a broader context thanks to the coordinating efforts of the Tagging Pacific Predators program (TOPP) which has assembled foraging data from several large marine vertebrates.

WORK COMPLETED

Through the ONR PCAD working group, we have initiated a dual analysis of tag loss and juvenile survival rate of southern elephant seals of Macquarie Island and Heard Island along with our data on northern elephant seals from Año Nuevo. Previous analysis of southern elephant seal data indicates tag loss is not independent between the two flipper tags on the same animals. If tag loss is assumed to be independent when, in fact, it is not, tag loss is biased low. Such a bias can lead to underestimates of survival. The analysis of southern elephant seals will help inform the model for northern elephant seals. In addition, comparisons of juvenile survival could lead to a better understanding of the impacts of environmental variability on capital breeders.

We received the full southern elephant dataset from Clive McMahon at the end of May. The models are complete and are an adaptation of the Bayesian Cormack-Jolly-Seber approach used with Antarctic fur seal data. Given the large sample size, we are able to investigate tag loss and survival by age, year, sex, cohort, and weight. The Macquarie Island dataset consists of 1500 animals tagged and resighted over a six year period. Below is a table (Table 1) of sample size of branded animal data from Macquarie Island that will be used to estimate tag loss. Resight effort so far has extended over a 16 year period.

Table 1. Number of branded and flipper-tagged individuals by sex and cohort for Macquarie Island southern elephant seals.

Cohort Year	Females	Males
1	412	427
2	219	439
3	328	309
4	376	354
5	328	372
6	406	377
7	355	341

With the exception of some minor changes, tag loss and survival rate estimates of branded southern elephant seals were completed in September 2010. Not all animals were branded, and juvenile survival rate estimates will incorporate an additional 1400 tagged-only animals. Also, in September 2010, we received pupping records for all Macquarie Island females in order to estimate reproductive rates.

Año Nuevo Breeding Season 2010

With funding from this grant, we were able to take advantage of the 2009/2010 El Niño event to look at potential changes in pup investment due to reduced foraging ability. We weighed 236 weaned pups, and those weights will be compared to weights taken during the next breeding season. Previous research has shown weaned pup weight is correlated with such an event.

To establish the impact of the El Niño on a larger group of known-age adult females, we collected morphometric measurements, including body mass, on 18 females ages 7-12 years old on postpartum day 5. Day 5 is our normal sampling day, so the new data will provide us with a larger sample to

compare to our previous female measurements at day 5. In addition, the effort to ensure known-age females were measured on day 5 required increased tag resight effort compared to other years when age was not a factor.

Resight Effort at Additional Rookeries

During the 2010 pupping/breeding season, resights were carried out at two additional rookeries: San Nicholas Island and Piedras Blancas. A team of three researchers, Autumn-Lynn Harrison, Nikky Teutschel, and Greg Breed, conducted resights at San Nicholas Island. Pat Morris conducted resights at Piedras Blancas. Both surveys occurred January 29-February 1, 2010.

RESULTS

Analysis of shouthern elephant seals from Macquarie Island showed that tag loss is dependent on age, sex, number of tags, and wean mass during the first two years. Males were more likely to lose their tags (Figure 1). All males had lost at least one tag by age 12, and most males had lost at least one tag by age 10. All 14-year-old or older males had lost both tags. Preliminary results for one cohort and sex (females, 1993 cohort) showed tag loss was lowest for weaned pups of median mass (Figure 2). In general, the probability of losing one tag going from the two-tag state to the one-tag state was lowest while the probability of losing one tag going from the one-tag state to the no-tag state was lower or the same as the probability of losing one tag going from the two-tag state to the no-tag state.

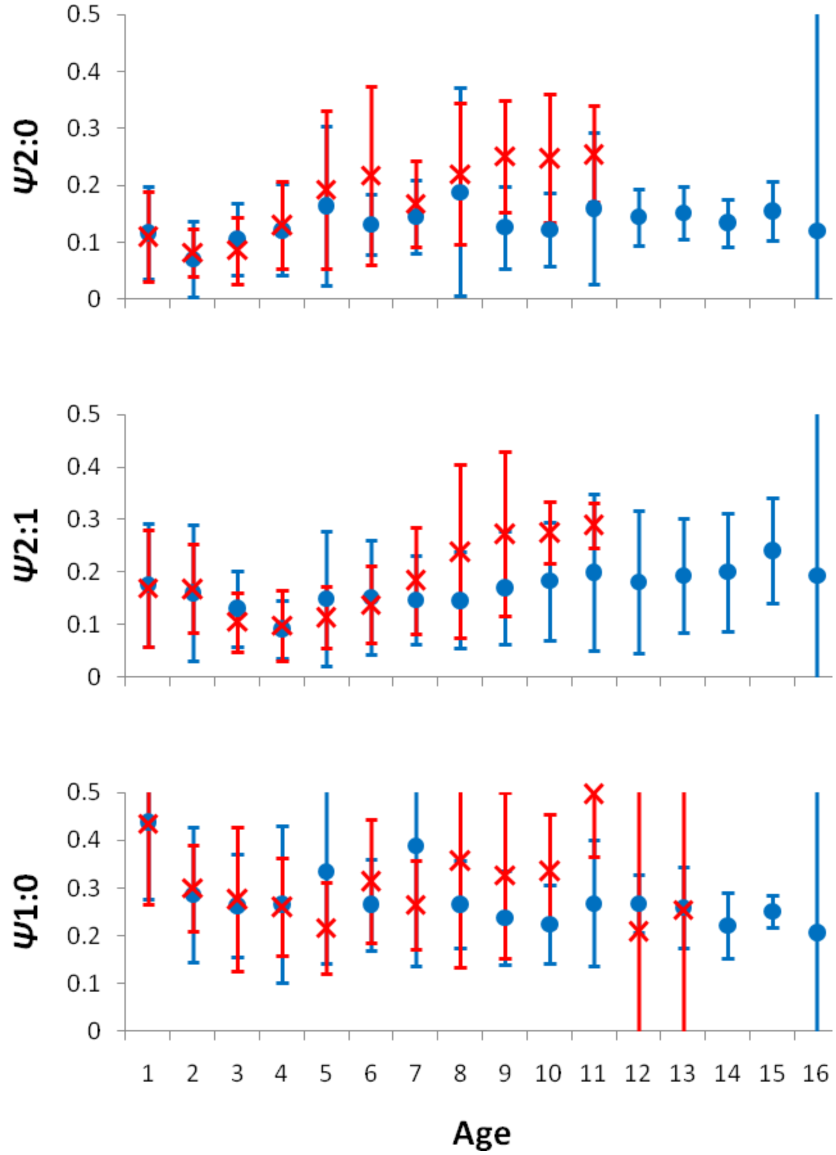

Figure 1. Tag loss as a function of age, sex, and number of tags. $\Psi_{x:y}$ is the probability of going from a x-tag state to a y-tag state where x and y are 0, 1, or 2. Males are red, and females are blue. Points are mean of means and bars are standard deviation of means by cohort.

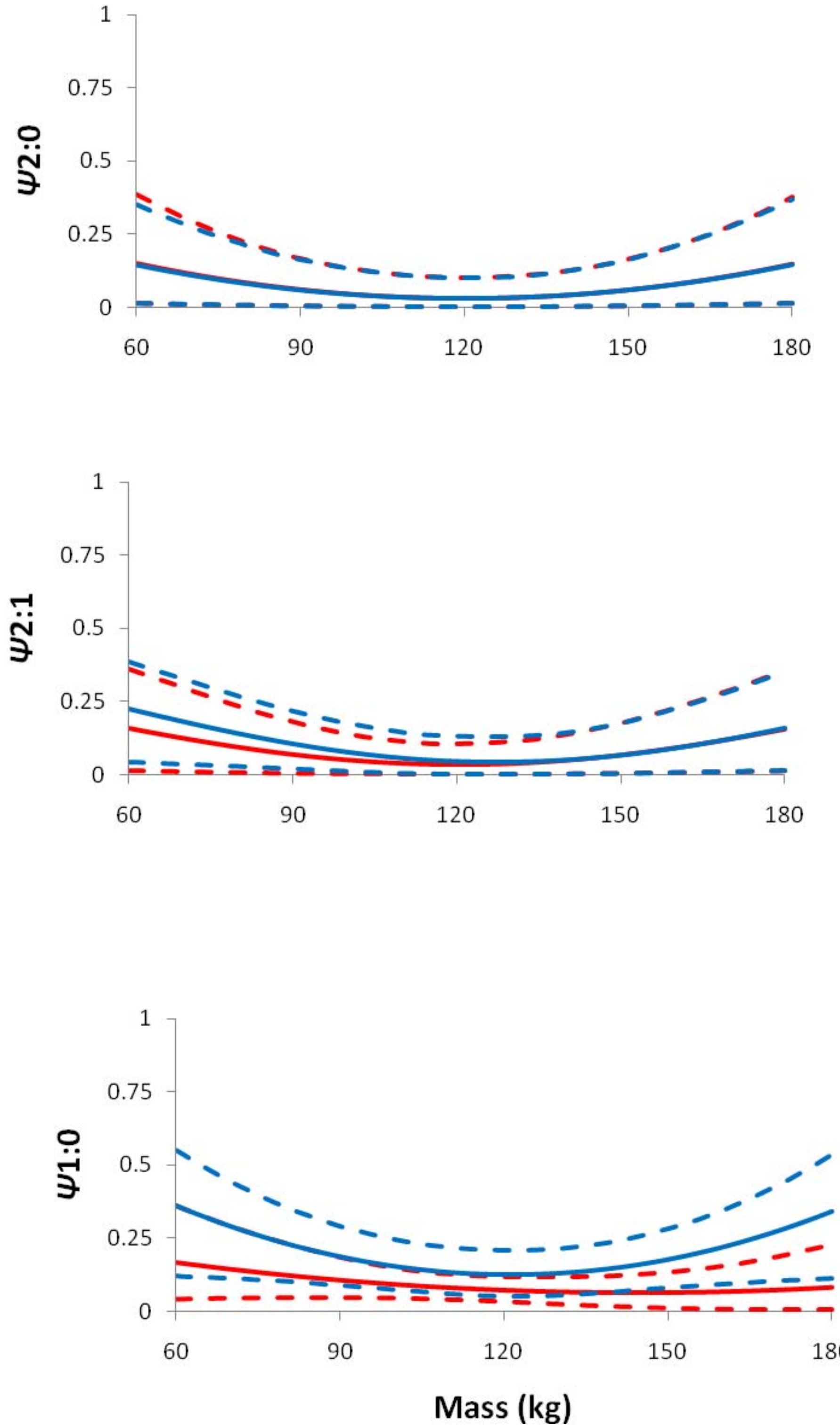

Figure 2. Posterior distributions of tag loss as a function of wean mass and age. $\Psi_{x:y}$ is the probability of going from a x-tag state to a y-tag state where x and y are 0, 1, or 2. Age class one is red, and age class two is blue. Solid lines represent mean tag loss and dashed lines are 95% posterior intervals.

Adult females weighed 500.1 kg ± 46.6 std five days post partum during the 2010 breeding/pupping season (n = 18). Weaned pups weighed 110.0 kg ± 23.8 std (n = 236), but those weights have not yet been corrected for wean date. Both adult female and wean pup weights will be compared with weights taken this coming pupping/breeding season. Changes in mass are critical to linking changes in demographic rates with disturbance. In this case, the disturbance is a supposed reduction in prey abundance due to El Niño, followed by the opposite conditions the following year (La Niña).

After an extensive search, no elephant seals on San Nicholas Island were seen with flipper tags from Año Nuevo (green tags). In addition, long-term researchers on the island claim they had not seen an elephant seal with a green flipper tag in 20 years of observations.

Of the 55 tags detected on females at Piedras Blancas, eight were green. Five tags were read to the identification level, and only one of those individuals was born at Año Nuevo. The others were tagged as juveniles and may have been born elsewhere. It is generally thought that elephant seals are continuing to disperse northward, but these data suggest some southward dispersal. In addition, one female was originally seen at Año Nuevo early in the season but gave birth at Piedras Blancas. Such movements show that we can not assume all females seen at a rookery will pup there.

IMPACT/APPLICATIONS

The 2009/2010 El Niño provides a rare opportunity to examine how elephant seals respond to a reduction in prey availability due to a natural disturbance. Weaning weight and female morphometric data will be used to inform and parameterize our models of the susceptibility and impact of an acoustic disturbance on elephant seals. These results are providing not only the short term response of elephant seals to a reduction in prey resources, but how such a reduction impacts their subsequent reproduction and survival. These are all very difficult parameters to otherwise measure.

Analysis of southern elephant seal mark-resight data have allowed us to create a Bayesian Cormack-Jolly-Seber model that can be modified to account for dispersal and used with northern elephant seals. In addition, tag loss probabilities from the southern elephant seal analyses will be used as priors for northern elephant seal tag loss. Mark-resight analysis, particularly in relation to mass, will provide us with survival and reproductive rate estimates that can be investigated in the context of the PCAD model.

Mass of females and weaned pups is the metric we use to determine changes in physiological condition in relation to disturbance. The weights collected during the 2009/2010 ENSO event will be compared with mass measurements from previous and future breeding/pupping seasons.

Efforts to resight tags at San Nicholas Island and Piedras Blancas were invaluable in determining the dispersion and movement patterns of individuals tagged at Año Nuevo. Without such data, regional survival and reproductive rate estimates can not be separated from movement probabilities in and out of an area, and any correlation between demographic rates and disturbance would be unconvincing.

RELATED PROJECTS

JIP: Relating Behavior and Life Functions to Populations Level Effects in Marine Mammals: An empirical and modeling effort to develop the PCAD model. Contract JIP 22 07-23

REFERENCES

None.

PUBLICATIONS

Robinson, P.W., Simmons, S.E., Crocker, D.E., Costa, D.P. 2010. Measurements of Foraging Success in a Highly Pelagic Marine Predator, the Northern Elephant Seal. Journal of Animal Ecology DOI: 10.1111/j.1365-2656.2010.01735.x

Costa, D.P. 2010. A Bioenergetics Approach to Developing the PCAD Model. 2nd International Conference on the Effects of Noise on Aquatic Life, Cork Ireland August 2010. Popper, A. and Hawkins, T. eds. Springer, New York, NY, U.S.A.